

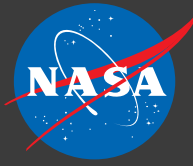
# Lessons Learned in Thermal Coatings from the DSCOVR Mission

*Nithin S. Abraham*

*NASA Goddard Space Flight Center, Greenbelt, Maryland 20771  
Code 546 Contamination and Coatings Engineering Branch*

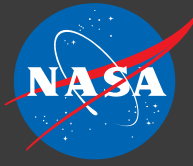
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Wednesday, July 29, 2015 to Friday, July 31, 2015

# Overview

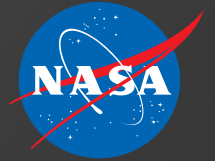


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# Abstract



Finding solutions to thermal coating issues on the Deep Space Climate Observatory (DSCOVR) mission was a very challenging and unique endeavor. As a passive thermal control system, coatings provide the desired thermal, optical, and electrical charging properties, while surviving a harsh space environment. DSCOVR mission hardware was repurposed from the late 1990s satellite known as Triana. As a satellite that was shelved for over a decade, the coating surfaces consequently degraded with age, and became fairly outdated. Although the mission successfully launched in February 2015, there were unfamiliar observations and unanticipated issues with the coating surfaces during the revival phases of the project. For example, the thermal coatings on DSCOVR experienced particulate contamination and resistivity requirement problems, among other issues. While finding solutions to these issues, valuable lessons were learned in thermal coatings that may provide great insight to future spaceflight missions in similar situations.



# Background

- ❖ *Overview of DSCOVER Mission*
- ❖ *Overview of DSCOVER Thermal Coatings*

# Background

## ■ Deep Space Climate Observatory (DSCOVR) Mission

### ■ Earth observation and space weather satellite

- Orbits between Earth and the sun at the Lagrange point 1 (L1)
- Successfully launched on February 11, 2015
  - *SpaceX Falcon 9 launch vehicle from Cape Canaveral, Florida*

### ■ Planned mission lifetime is 5 years to provide:

- More advanced and reliable warnings of solar wind conditions
  - *Harmful solar activity can potentially impact power grids, communications systems, and satellites close to Earth*
- Measurements of the radiation reflected and emitted by Earth
- Images of the sunlit side of Earth for science applications

### ■ Key partners consist of:

- National Oceanic and Atmospheric Administration (NOAA)
- NASA Goddard Space Flight Center (GSFC) [*Spacecraft*]
- U.S. Air Force (USAF) [*Launch Vehicle*]

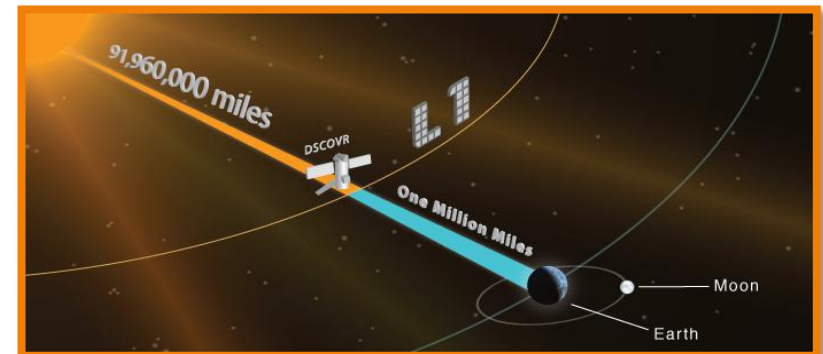


Photo Credit: NOAA <<http://www.nesdis.noaa.gov/DSCOVR/mission.html>>

# Background

- DSCOVR's mission hardware was **repurposed** from the late 1990s satellite known as **Triana**, which was a previously canceled NASA earth science mission



Photo Credit: NOAA <[http://www.nesdis.noaa.gov/DSCOVR/images/DSCOVR-Logo\\_NOAA\\_NASA\\_USAF.jpg](http://www.nesdis.noaa.gov/DSCOVR/images/DSCOVR-Logo_NOAA_NASA_USAF.jpg)>

2001

- The Triana satellite was canceled in November and afterwards put into storage at NASA GSFC

2008

- NOAA and USAF removed the Triana satellite from storage and tested it as a solution to meet their space weather requirements

2012

- The refurbishment of the Triana satellite began as part of the DSCOVR mission's pre-launch activities

2015

- DSCOVR successfully launched in February and reached its final orbit in June

# Background

## ■ Thermal Coatings

- Serves as a passive thermal control system on the spacecraft
- Provides **thermal**, **optical**, and/or **electrical charging** properties to meet mission requirements while surviving the harsh space environment



Photo Credit: NOAA <[http://www.nesdis.noaa.gov/images/news\\_archives/GSFC-2015-303-006\\_010.jpg](http://www.nesdis.noaa.gov/images/news_archives/GSFC-2015-303-006_010.jpg)>





# Background

- Although DSCOVR launched successfully, there were many **unfamiliar observations** and **unanticipated issues** with the thermal coating surfaces during the revival phases of the mission

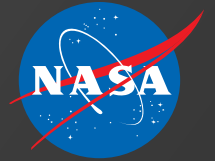
## EXPLANATION

- Although the root cause is **still unclear**, the many anomalies that were observed on DSCOVR may be correlated to the age and storage of the coatings. As a satellite that was shelved in storage for over a decade, the coating surfaces consequently **degraded with age** and **continued handling**, as well as became **fairly outdated**.
- Finding solutions to DSCOVR's thermal coating issues was a very **challenging** and **unique** endeavor

## CHALLENGES

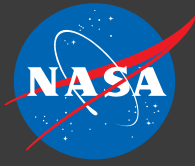
- The fragile condition of the existing coatings created challenges that involved **particulate contamination** and **electrostatic discharge/resistivity**
- Valuable lessons were learned in thermal coatings that may provide insight to future spaceflight missions in similar situations





# Lessons Learned

- ❖ *Coatings Lesson 1*
- ❖ *Coatings Lesson 2*
- ❖ *Coatings Lesson 3*
- ❖ *Examples*



# Lessons Learned

The following are the lessons learned in thermal coatings from the DSCOVR mission:

- **LESSON 1.**

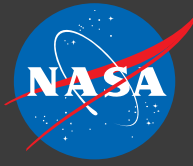
It is recommended to replace thermal coatings that have significantly aged and/or have been placed in dry purged storage conditions for an extended period. Aged coatings that show physical signs of damage and “wear and tear” are more fragile, likely to damage even further with continued handling, and have an increased risk of generating particulate contamination.

- **LESSON 2.**

It is recommended to verify the electrical resistivity of thermal coatings that have significantly aged and/or have been placed in dry purged storage conditions for an extended period. Aged coatings may have been damaged and may not exhibit the required conductivity. Aged coatings may also have outdated properties, and could have other replacement options available to meet mission requirements.

- **LESSON 3.**

It is recommended to treat most thermal coatings as “no touch surfaces” whether they have aged over time in storage or have been freshly applied during refurbishment. Although this is challenging, avoiding surface contact with the coating will reduce any risk of potential damage and contamination on a particulate or molecular level.



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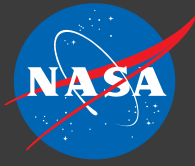
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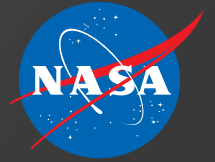
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# Examples

- Below are some examples of thermal coating challenges that resulted in these valuable lessons learned:

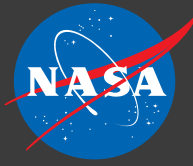
Thermal Coating Surface	Problems	Risk	Solutions
White Silicate Radiator Coating, GSFC NS43C	Dry, aged powdery coating that generated particles with continued handling, and had outdated resistivity properties	Increased risk to particulate contamination and electrostatic discharge (ESD) anomalies	Vacuumed/cleaned loose particles off, touched up/re-coated damaged surfaces with Alion Z-93C55, and designated as a “no touch surface”
GSFC Silver Composite Coating, CCAg with Indium Tin Oxide (ITO)	Showed signs of crazing and delamination, which may have also damaged the conductive ITO layer	Increased risk to particulate contamination and ESD anomalies	Replaced with new ITO CCAg and designated as a “no touch surface”
Internal Baffle Coating	Structurally damaged due to age/storage/handling	Increased risk to particulate contamination	Removed coating and re-applied with a polyurethane Coating, and designated as a “no touch surface”
Germanium Black Kapton (GBK) on Multi-Layer Insulation (MLI) Blankets	Missing layers of GBK due to “wear and tear” damage	Increased risk of thermal, contamination and ESD anomalies	Replaced outer layers of the MLI blankets with new material
Kapton Multi-Layer Insulation (MLI) Blankets with Indium Tin Oxide (ITO)	Outer layers were damaged indicating lack of presence of the conductive ITO layer	Increased risk to ESD anomalies	Replaced outer layer s of earth facing Kapton MLI blankets with GBK



# Example 1.

❖ *Analysis of Lessons Learned on  
DSCOV R White Silicate Coatings*

# Ex. 1 White Silicate Coatings



## COATING

- **GSFC NS43C** is a white silicate based thermal control coating developed in the 1970s

## HARDWARE

- Applied on most of the radiator surfaces of DSCOVR (previously Triana) in the late 1990s

### GSFC White Paint NS43C

#### Thermal Property

Thermal Property	
Solar Absorptance ( $\alpha_s$ )	0.20
Normal Emittance ( $\epsilon_N$ )	0.92

Source: Kauder, L., "Spacecraft Thermal Control Coatings References", NASA/TP-2005-212792, December 2005, p. 47

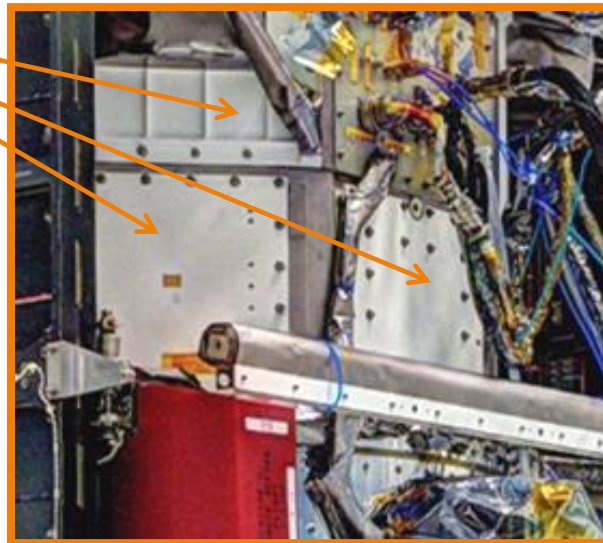
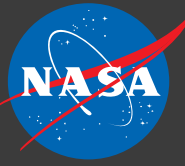


Photo Credit: NOAA <[http://www.nesdis.noaa.gov/images/news\\_archives/GSFC-2015-303-006\\_010.jpg](http://www.nesdis.noaa.gov/images/news_archives/GSFC-2015-303-006_010.jpg)>





# Ex. 1 White Silicate Coatings



## IMPACT TO CONTAMINATION AND ESD

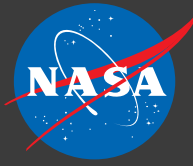
### PROBLEMS

- NS43C coated surfaces were housed in a nitrogen purged storage environment for over a decade. This resulted in a **dry powdery aged coating** that generated particles during the refurbishment phases of the project (*contamination problems*)
- Physical signs of damage and “wear and tear” were also present. These damaged surfaces are fragile and thus, with continued handling were more susceptible to generate particles (*contamination problems*)
  - *For example, spots of bare aluminum due to coating removal and dark “scruff” marks*
- At the time, NS43C was the best available coating to meet thermal requirements and dissipate charge on radiator surfaces. However, NS43C is no longer being manufactured these days and have **outdated resistivity properties** (*electrostatic discharge problems*)
  - *Newer white silicate coatings exist to meet today’s mission requirements*



Photo Credit: NASA/DSCOV

# Ex. 1 White Silicate Coatings



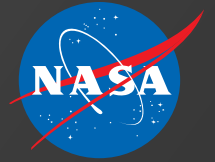
## IMPACT TO CONTAMINATION AND ESD

### SOLUTIONS

- NS43C coated surfaces were periodically vacuumed and gently wiped down by coatings experts to clean/remove loose particles
- Touched up bare aluminum spots on the radiators using Z-93C55. The non-repairable surfaces were stripped and re-coated with Z-93C55
  - ***Alion Z-93C55** is a white electrically dissipative silicate based thermal control coating with resistivity properties to meet today's mission requirements*
- Designated all white coating surfaces as “**no touch surfaces**” to minimize particle generation from handling through out the pre-launch phases of the project

### FUTURE WORK

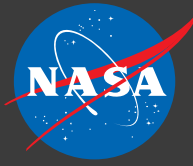
- Evaluate effects of dry storage environments on coatings for extended periods and study new mitigation methods to reduce or encapsulate coating particulation



## Example 2.

❖ *Analysis of Lessons Learned on  
DSCOV R Reflective Thin Films*

# Ex. 2 Reflective Thin Films



## COATING

- **GSFC Silver Composite Coating (CCAg)** is a vapor deposited thin film coating consisting of layers of silicon oxide, aluminum oxide, and silver ( $\text{SiO}_2/\text{Al}_2\text{O}_3/\text{Ag}/\text{Al}_2\text{O}_3$ ). Layers of **Indium Tin Oxide (ITO)** may also be applied as a top layer for electrical conductivity purposes.
  - *Historically, CCAg is very robust (if applied properly) with a low chance of removal from the substrate. ITO is typically very fragile with a high chance of removal from surface damage.*

## HARDWARE

- Applied to the “peacock” shaped radiator on the **Faraday Cup** in the late 1990s
  - *DSCOVR’s Faraday Cup will monitor the speed and direction of positively charged solar wind particles*

### GSFC CCAg ITO on 3 mil Kapton

Thermal Property	
Solar Absorptance ( $\alpha_s$ )	0.08
Normal Emittance ( $\epsilon_N$ )	0.72

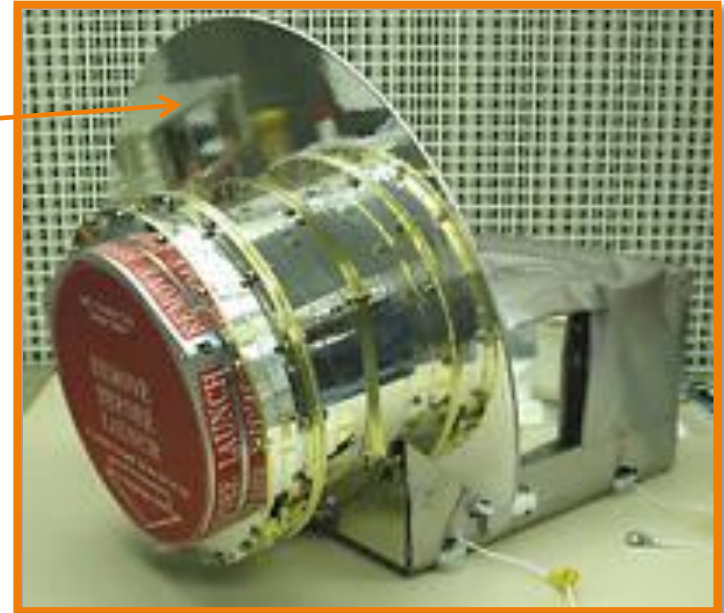
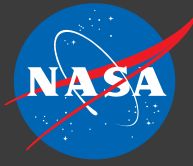


Photo Credit: NASA <<http://www.nasa.gov/content/goddard/dscovr-offering-a-new-view-of-the-solar-wind>>

# Ex. 2 Reflective Thin Films



## IMPACT TO CONTAMINATION AND ESD

### PROBLEMS

- Visible signs of crazing, micro-cracking, and delamination effects were discovered on the CCAg coated area of the peacock shaped radiator
- Due to its extended time in storage, the Kapton substrate probably retained some moisture, and thus caused adhesion issues between the CCAg and Kapton
- This adhesion anomaly increases risk due to the Faraday Cup's sensitivity to *particulate contamination* and *electrostatic discharge* (ESD) charging
  - *May pose a threat for the dispersion of conductive metal particles on the Faraday Cup*
  - *May have damaged or removed the ITO layer on the CCAg coating*



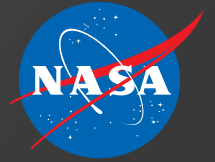
Photo Credit: NASA/DSCOV

### SOLUTIONS

- Re-deposited ITO CCAg onto 3 mil Kapton and applied onto peacock shaped radiator of the Faraday Cup

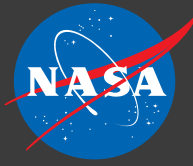
### FUTURE WORK

- Apply reflective thin films onto metal substrate (or hardware surface) rather than Kapton to reduce impact of moisture damage when in storage for extended periods of time



# Conclusions

# Lessons Learned



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# Acknowledgements

- Valuable thermal coatings support on the DSCOVR mission was provided by individuals from NASA GSFC and Stinger Ghaffarian Technologies, Inc (SGT):
  - Mark Hasegawa      NASA GSFC/Code 546
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  - Grace Miller        SGT Inc/Code 546
  - George Harris      SGT Inc/Code 546
  - Kenny O'Connor   SGT Inc/Code 546
  - Lon Kauder         SGT Inc/Code 546
  - Jim Heaney         SGT Inc/Code 546

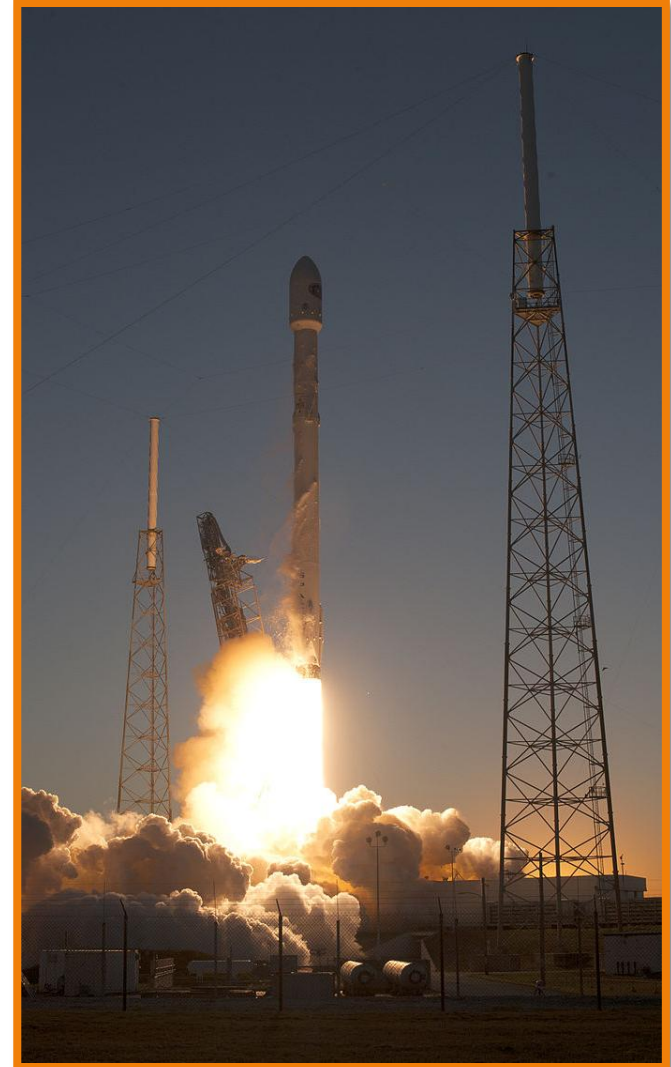
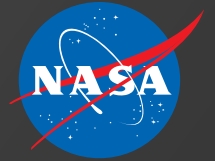


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# Contact Information

***Nithin S. Abraham***

**Thermal Coatings Engineer**

NASA Goddard Space Flight Center

Code 546, Contamination and

Coatings Engineering Branch

E-mail: [nithin.s.abraham@nasa.gov](mailto:nithin.s.abraham@nasa.gov)

Phone: (301) 614-7070